Anatomic distribution and mortality of arterial injury in the wars in Afghanistan and Iraq with comparison to a civilian benchmark

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Objective: **The purpose of this study was to examine the anatomic distribution and associated mortality of combat-related vascular injuries comparing them to a contemporary civilian standard.**

Design: **The Joint Trauma Theater Registry (JTTR) was queried to identify patients with major compressible arterial injury (CAI) and noncompressible arterial injury (NCAI) sites, and their outcomes, among casualties in Iraq and Afghanistan from 2003 to 2006. The National Trauma Data Bank (NTDB) was then queried over the same time frame to identify civilian trauma patients with similar arterial injuries. Propensity score-based matching was used to create matched patient cohorts from both populations for analysis.**

Results: **Registry queries identified 380 patients from the JTTR and 7020 patients from the NTDB who met inclusion criteria. Propensity score matching for age, elevated Injury Severity Score (ISS; >15), and hypotension on arrival (systolic blood pressure [SBP] <90) resulted in 167 matched patients from each registry. The predominating mechanism of injury among matched JTTR patients was explosive events (73.1%), whereas penetrating injury was more common in the NTDB group (61.7%). In the matched cohorts, the incidence of NCAI did not differ (22.2% JTTR vs 26.6% NTDB; $P = .372$), but the NTDB patients had a higher incidence of CAI (73.7% vs 59.3%; $P = .005$). The JTTR cohort was also found to have a higher incidence of associated venous injury (57.5% vs 23.4%; $P < .001$). Overall, the matched JTTR cohort had a lower mortality than NTDB counterparts (4.2% vs 12.6%; $P = .006$), a finding that was also noted among patients with NCAI (10.8% vs 36.4%; $P = .008$). There was no difference in mortality between matched JTTR and NTDB patients with CAI overall (2.0% vs 4.1%; $P = .465$), or among those presenting with Glasgow Coma Scale (GCS) <8 (28.6% vs 40.0%; $P = 1.00$) or shock (SBP <90; 10.5% vs 7.7%; $P = 1.00$). The JTTR mortality rate among patients with CAI was, however, lower among patients with ISS >15 compared with civilian matched counterparts (10.7% vs 42.4%; $P = .006$).**

Conclusions: **Mortality of injured service personnel who reach a medical treatment facility after major arterial injury compares favorably to a matched civilian standard. Acceptable mortality rates within the military cohort are related to key aspects of an organized Joint Trauma System, including prehospital tactical combat casualty care, rapid medical evacuation to forward surgical capability, and implementation of clinical practice guidelines. Aspects of this comprehensive combat casualty care strategy may translate and be of value to management of arterial injury in the civilian sector. (J Vasc Surg 2012;56:728-36.)**

After the start of military operations in Afghanistan and Iraq, the need to coordinate patient movement and collect information from both theaters and throughout a 6000- to 7000-mile aeromedical evacuation chain into one repository became clear.[1,2] Modeled after civilian trauma systems and the American College of Surgeons' National Trauma Data Bank (NTDB), the US military developed the Joint Theater Trauma System (JTTS) and an associated Joint Trauma Theater Registry (JTTR).[1-3] The JTTR provides the US military's combat casualty care mission the ability to perform data-driven, process improvement designed to reduce morbidity and mortality.[4]

As a leading cause of morbidity and mortality, vascular trauma is a focus of the military's combat casualty care system. Although it comprises a minority of trauma, vascular disruption is the leading cause of exsanguination, limb ischemia, and amputation.[5-8] Tourniquets and pressure dressings with or without hemostatic agents have been shown to effectively control bleeding from extremities and compressible sites and improve survival in the process.[9-11] In contrast, hemorrhage from noncompressible locations such as the torso remains poorly addressed and has been identified as the leading cause of potentially preventable death in combat.[6-8] Other studies have documented management techniques of vascular injury, including use of autologous vein for arterial reconstruction, the efficacy of temporary shunts, and selective use of endovascular tech-

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Table I. Demographics (unmatched)

Characteristic	*Total (n = 7400)*	*JTTR (n = 380)*	*NTDB (n = 7020)*	P *value*
Age (mean ± SD)	31.6 ± 10.0	25.7 ± 6.5	32.0 ± 10.1	<.001
Male (%)	83.7	98.7	82.8	<.001
SBP <90 (%)	26.9	20.5	27.3	.005
GCS ≤8 (%)	35.7	34.3	35.8	.584
ISS >15 (%)	66.7	44.5	67.9	<.001
Mechanism of injury				
Blunt	47.6	3.2	50.0	<.001
Penetrating	48.9	28.2	50.0	
Explosion	3.5	68.7	0.0	

GCS, Glasgow Coma Scale; *ISS*, Injury Severity Score; *JTTR*, Joint Theater Trauma Registry; *NTDB*, National Trauma Data Bank; *SBP*, systolic blood pressure.

niques.[5,12-15] Finally, a recent epidemiologic study using the JTTR demonstrated that the rate of vascular injury in modern combat is five times that reported in previous wars.[16,17]

Despite the need to reduce hemorrhage-related mortality, there have been no JTTR-based studies characterizing mortality after arterial trauma in the wars in Afghanistan and Iraq. Furthermore, the distribution of compressible and noncompressible sites of arterial injury and their associated mortality within the JTTR is unknown. Finally, studies have yet to compare the anatomic distribution of and mortality from arterial injury in the wartime setting to that managed in the US civilian trauma system. The objective of this study was to characterize major arterial injury within the JTTR, including patterns of compressible and noncompressible injury and in-hospital mortality. In addition, the objective of this study was to compare the anatomic distribution and mortality after wartime arterial injury to that sustained in the civilian setting.

METHODS

The JTTR and the NTDB, version 7.0, were used for identification of comparison cohorts. Inclusion criteria consisted of patients aged 18 to 55 years identified as having sustained a major arterial injury by International Classification of Disease, 9th revision, injury or procedure codes between January 2003 and December 2006. Inclusion dates were chosen in order to obtain a representation of wartime arterial injury in US service personnel during a period in which hostilities were the greatest and occurring in two simultaneous theaters of war. Selection of these inclusion dates also allowed for use of a single NTDB Research Data Set from NTDB version 7.0 (2002-2006).

Major arterial injuries were defined by location (named axial artery) and categorized into two groups based on their ability to be controlled with compression or tourniquets. Noncompressible arterial injury (NCAI) was defined as injury to the aorta or the axillary, subclavian/innominate, carotid, or iliac arteries whereas compressible arterial injury (CAI) was defined as injury to the brachial, femoral, or popliteal arteries. For purposes of the study, and to emphasize inclusion of the most relevant of vascular injuries, distal extremity (tibial and forearm) or minor vascular injuries, including isolated venous injuries, were excluded. Demographic and clinical data, including age, gender, mechanism of injury, systolic blood pressure (SBP), Glasgow Coma Scale (GCS), and Injury Severity Score (ISS), were recorded. The primary outcome examined was in-hospital mortality or death from any cause during the initial hospitalization resulting from the event which resulted in the vascular injury.

Statistical analysis. Sample means and SEs of measurement of continuous variables were calculated for both overall cohorts (JTTR and NTDB). Differences were tested with a two-tailed *t*-test. A *P* value of <.05 was considered significant. Due to differences between civilian and military patient populations, propensity score matching was used to identify a similar cohort of patients within the military JTTR and civilian NTDB overall groups to provide a more accurate comparison between them.[18] Patients within each overall cohort were Caliper-matched based on the following factors: age (less than 31 years), gender (male), first systolic blood pressure (less than 90 mm Hg), and ISS (greater than 15).[19] After matching, examination of the like cohorts consisted of logistic regression analysis to determine variables predictive of mortality.

Frequency distributions of demographics and clinical characteristics for the total sample and both cohorts (matched and unmatched) were calculated. Homogeneity of the groups was tested with contingency tables and either χ^2 or Fisher exact test. JTTR and NTDB cohorts (matched and unmatched) were assessed for normality of distributions, equality of variances, and independence. Mortality odds ratios and confidence intervals were calculated for both JTTR and NTDB cohorts (matched and unmatched). Subgroup mortality was also calculated for cohorts based after stratification based on key clinical characteristics (NCAI vs CAI and either GCS <8, SBP <90 mm Hg, or ISS >15).

RESULTS

Overall (unmatched) cohort analysis

Demographics and anatomic distribution of arterial injury. Individual registry queries identified 380 patients from the JTTR and 7020 patients from the NTDB who met inclusion criteria (Table I). In these unmatched groups, patients within the JTTR were younger (25.7 ±

Table II. Anatomic patterns of injury (unmatched)

Location	*JTTR (%)*	*NTDB (%)*	P *value*
NCAI			
Any NCAI	27.9	61.4	<.001
Carotid	8.9	8.2	.623
Thoracic aorta	1.6	28.0	<.001
Innominate or subclavian	3.7	6.4	.035
Axillary	5.5	4.6	.404
Abdominal aorta	0.8	6.1	<.001
Iliac artery	7.4	9.9	.100
CAI			
CAI only	65.8	38.6	<.001
Brachial	18.9	11.1	<.001
Femoral	31.6	17.5	<.001
Popliteal	15.3	11.8	.043

CAI, Compressible arterial injury; *JTTR,* Joint Theater Trauma Registry; *NCAI,* noncompressible arterial injury; *NTDB,* National Trauma Data Bank.

6.5 years vs 32.0 ± 10.1 years; $P < .001$) and predominately men (98.7% vs 82%; $P < .001$). Of those with major arterial injury, the NTDB cohort was more severely injured (ISS >15; 67.9% vs 44.5%; $P < .001$ and SBP <90; 27.3% vs 20.5%; $P = .005$). Mechanisms of injury were also different with a preponderance of explosion-type injury in the JTTR cohort (68.7%) and a minority of blunt trauma (3.2%), whereas the NTDB cohort was evenly split between blunt and penetrating injuries (50%, respectively). Table II presents the anatomic distribution of arterial injury within the unmatched cohorts. Patients within the NTDB demonstrated a higher incidence of NCAI (61.4% vs 27.9%; $P < .001$) with the primary difference being the higher percentage of thoracic and abdominal aortic injuries in this group (Table II). CAI was the predominant injury pattern in the JTTR cohort (55.5%) with the majority involving the femoral artery (36.6% of total). There was also a higher incidence of concomitant venous injury in the JTTR cohort (54.5% vs 18.4%; $P < .001$) and vascular injuries at multiple sites (10.3% vs 3.5%; $P < .001$).

Mortality. Mortality associated with major arterial injury in the unmatched cohorts is shown in Fig 1. Patients in the JTTR cohort had an overall lower mortality than those in the NTDB group (8.4% vs 28.6%; $P < .001$), a finding that was also present in those with NCAI (11.9% vs 42.7%; $P < .001$). Mortality in those with arterial injury in compressible sites (CAI) was the same in the JTTR and NTDB groups (4.3% vs 6.2%; $P = .249$). As shown in Fig 2, in the unmatched comparison, mortality was lower in the JTTR than the NTDB group in those with GCS <8 (22.5% vs 66.7%; $P < .001$), those with ISS >15 (14.2% vs 40.8%; $P < .001$), and those presenting with shock (SBP <90; 25.0% vs 60.2%; $P < .001$).

Matched cohort analysis

Demographics and anatomic distribution of arterial injury. The propensity scoring algorithm identified 167 patients from the JTTR and NTDB who were matched for age, elevated ISS (>15), and hypotension on arrival (SBP <90; Table III). In these matched cohorts, mechanism of injury differed with explosive type prevailing in the JTTR (73.1%), whereas penetrating type was more common in the NTDB group (61.7%). Within the matched cohorts, the incidence of NCAI did not differ (22.2% JTTR vs 26.6% NTDB; $P = .372$; Table IV). A greater incidence of CAI was found in the NTDB cohort (73.7% vs 59.3%; $P = .005$), although no difference was identified within the individual component arterial structures that comprised our defined CAI (brachial, femoral, or popliteal arteries). As in the unmatched comparison, there was a greater incidence of associated major venous injury in the JTTR cohort (57.5% vs 23.4%; $P < .001$).

Mortality. Mortality associated with arterial injury in the matched cohorts is shown in Fig 3. Patients in the JTTR cohort had an overall lower mortality than those in the NTDB group (4.2% vs 12.6%; $P = .006$), a finding that was also present in those with NCAI (10.8% vs 36.4%; $P = .008$). Mortality in those with CAI was not significantly different between the matched JTTR and NTDB groups (2.0% vs 4.1%; $P = .465$). As shown in Fig 4, there was no difference in mortality between the matched JTTR and the NTDB groups in those with GCS <8 (28.6% vs 40.0%; $P = 1.00$) or those presenting with shock (SBP <90; 10.5% vs 7.7%; $P = 1.00$). In the matched cohort analysis, mortality was lower in the JTTR group than the NTDB group in those with ISS >15 (10.7% vs 42.4%; $P = .006$; Fig 4).

DISCUSSION

This study is the first to use the JTTR to report mortality after wartime arterial injury. These results demonstrate that, among patients with this injury pattern who survive to a treatment facility, 8% subsequently die of their wounds. Findings also show that one-quarter of arterial injuries in combat are in an anatomic region not conducive to compression or tourniquet application, a pattern of injury with higher rates of shock and death. Despite the challenges of the austere environment, this study demonstrates that among those that reach a medical facility, mortality after wartime arterial injury compares favorably to a matched cohort of US civilian patients with similar injuries.

Documentation of vascular injury in the wars in Afghanistan and Iraq began with a report on US service personnel returning to Walter Reed Army Medical Center between 2001 and 2004.[20] Starnes et al[21] also provided insight into the challenges associated with vascular injury on the battlefield, a report that was followed by publications from the Balad Vascular Registry.[5] Reports from the Air Force Theater Hospital documented many aspects of acute vascular injury management, including autologous vein for arterial reconstruction, efficacy of temporary shunts, and even selective utilization of endovascular techniques.[5,12-15] The original presentation of the Balad Vascular Registry reported a perioperative mortality rate of 4.3% which included only intraoperative and immediate postoperative deaths before aeromedical evacuation out of the theater of war.[5] The mortality rate of 8.4% in the

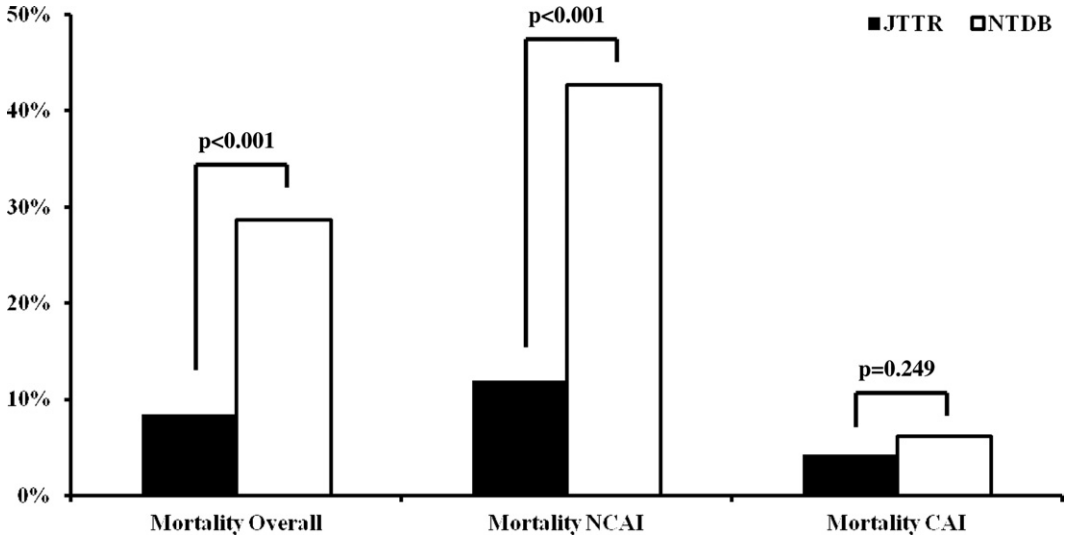

Fig 1. Unmatched comparison Joint Theater Trauma Registry (*JTTR*) vs National Trauma Data Bank (*NTDB*). *CAI,* Compressible arterial injury; *NCAI,* noncompressible arterial injury.

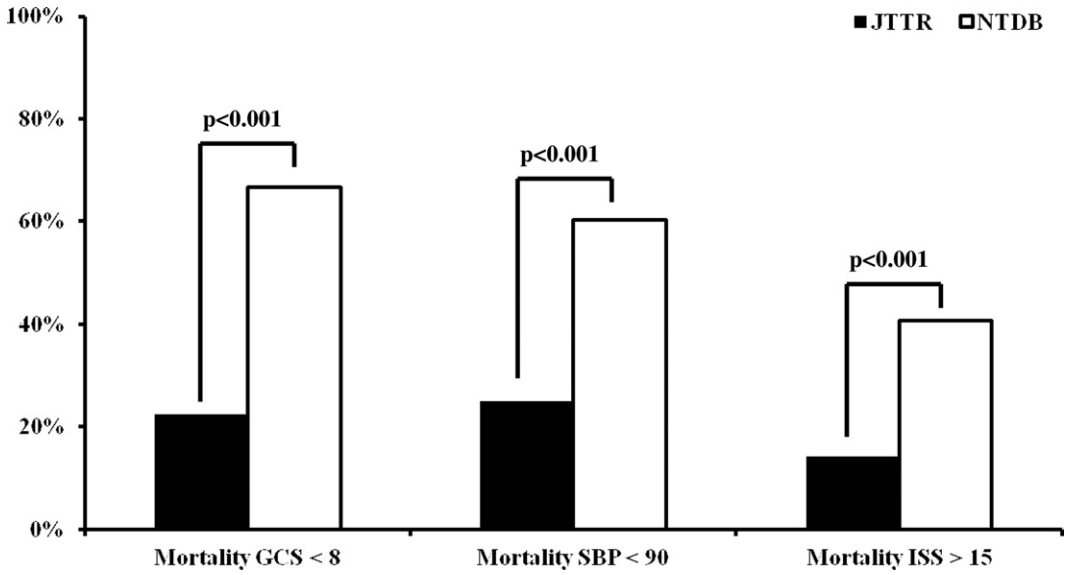

Fig 2. Unmatched comparison Joint Theater Trauma Registry (*JTTR*) vs National Trauma Data Bank (*NTDB*). *GCS,* Glasgow Coma Scale; *ISS,* Injury Severity Score; *SBP,* systolic blood pressure.

current study confirms and extends the Balad Vascular Registry report providing an account from two simultaneous theaters of war and including deaths that occurred at any time along the route of evacuation, including later at level V treatment facilities in the United States.

The current study provides insight into the distribution of arterial trauma and is the first registry-based report to characterize mortality associated with compressible and noncompressible injury in military and civilian cohorts (Figs 1 and 3). Because arterial disruption and hemorrhage has been identified as the leading cause of potentially preventable death after major trauma, an understanding of these categories is important.[6-8] From an anatomic perspective, CAI is defined as disruption of a major artery of the extremity or cervical region resulting in hemorrhage amenable to direct pressure or application of a tourniquet. In contrast, NCAIs are those within the anatomic limits of the torso which require opening of either the abdomen or thorax to achieve hemostasis. The observation in the current study that NCAI was more common in the national population (61% vs 28%) reflects the frequency of motor vehicle crashes as the cause of blunt thoracic and abdominal aortic injuries in civilians (Table II). The lower rate of NCAI in the military cohort may also suggest a beneficial

Table III. Demographics (matched)

Characteristic	*JTTR (n = 167)*	*NTDB (n = 167)*	P *value*
Age (mean ± SD)	22.9 ± 2.9	23.1 ± 3.4	.356
Male (%)	100	100	NA
SBP <90 (%)	12.0	7.8	.200
GCS ≤8 (%)	11.4	3.0	.004
ISS >15 (%)	16.8	19.8	.479
Mechanism of injury			
Blunt	1.2	38.3	<.001
Penetrating	25.7	61.7	
Explosion	73.1	0	

GCS, Glasgow Coma Scale; *ISS,* Injury Severity Score; *JTTR,* Joint Theater Trauma Registry; *NA,* not applicable; *NTDB,* National Trauma Data Bank; *SBP,* systolic blood pressure.

Table IV. Anatomic patterns of injury (matched)

Location	*JTTR (%)*	*NTDB (%)*	P *value*
NCAI			
Any NCAI	22.2	26.6	.372
Carotid	6.6	7.8	.672
Thoracic aorta	0.6	3.6	.121
Innominate or subclavian	1.2	3.0	.448
Axillary	6.6	4.8	.479
Abdominal aorta	0.0	1.2	.498
Iliac artery	7.2	6.0	.659
CAI			
CAI only	59.3	73.7	.005
Brachial	21.6	32.3	.026
Femoral	27.5	21.0	.160
Popliteal	19.2	22.2	.499

CAI, Compressible arterial injury; *JTTR,* Joint Theater Trauma Registry; *NCAI,* noncompressible arterial injury; *NTDB,* National Trauma Data Bank.

role of force protection measures such as body armor to mitigate torso vascular injury. Given the lethality of this injury pattern, it is notable that noncompressible sites still comprise a quarter of arterial injuries in military personnel. The prevalence of CAI (ie, extremity) in the JTTR cohort of the current study (Table II) is consistent with other reports on wartime vascular injury and confirms the need for effective use of tourniquets by medics in the prehospital setting.[22-24]

It is important to point out that while the two categories, compressible and noncompressible, have formed the basis for studying sites of hemorrhage, a third and more functional category has emerged, junctional injury. Junctional vascular injury includes hemorrhage from major vessels at or just distal to their exit from the torso.[6-8] At these locations, bleeding from the common carotid, axillary, and common femoral arteries is often not controlled by manual techniques, rendering them noncompressible. In this context, the current study categorized carotid and axillary injuries as noncompressible. While defining these injuries in such a manner is sensible, this method increases the percentage of injuries categorized as NCAI (28% of total; Table II) relative to older studies. For example, the Balad Vascular Registry, which described noncompressible arterial injury as that occurring only to torso vessels, reported a rate of 8.9%. In that same study, if cervical and axillary injuries had been categorized as noncompressible, the NCAI rate would have been 29%, nearly identical to the findings in the current study. Finally, it should be noted that defining axillary and cervical injuries as noncompressible may also decrease the mortality of this category as there are instances when these injuries are functionally compressible and therefore less lethal.

Unlike the axillary and carotid arteries, femoral artery injuries in the current study were all categorized as compressible (CAI). This definition was based on the report from Woodward et al[12] on the management of femoral popliteal trauma which noted that only the most proximal segment of the femoral vessel is noncompressible. In that report, proximal common femoral injuries were rare and accounted for <5% of the total. Additionally, search codes for the registries do not allow for differentiation between the common, superficial, and deep femoral arteries. As such, in this study, it would not have been possible to discriminate between the very rare noncompressible and the much more frequent compressible femoral artery injuries. Although all femoral injuries were categorized as CAI in this study, it should be noted that there may have been rare instances of proximal injury not amenable to direct pressure or tourniquet application rendering them noncompressible and more lethal.

The observation of a favorable mortality rate in the military cohort of this study (Figs 1 and 3) is compelling and may be related to several factors. One method to improve outcomes after wartime vascular injury has included implementation of evidence-based clinical practice guidelines.[2,4] Fox et al[25,26] was among the first to demonstrate the importance of the JTTS Damage Control Resuscitation guideline in directing blood component-based resuscitation as part of vascular injury management. This study documented a change in resuscitation practices after modification of the clinical practice guidelines and suggested that this type of resuscitation during vascular repair allowed successful pursuit of limb and life. Resuscitation with a one-to-one ratio of red blood cells to plasma was subsequently shown to reduce mortality in military populations, and recently this approach has been accepted by civilian trauma centers.[27-29] It may be that the military's development and rapid adoption of this resuscitation practice explains, in part, the favorable survival in the JTTR cohort of the current study.

Reduced mortality within the military cohort may also be attributable to a number of additional factors inherent to military combat casualty care, including force protection measures such as body armor and vehicle design advancements. Prehospital care training and approaches, unique to the combat environment, and the principles used in the context of Tactical Combat Casualty Care also likely contribute.[11,30] Additionally, the strategies related to the very construct of the JTTS, including rapid medical evacuation

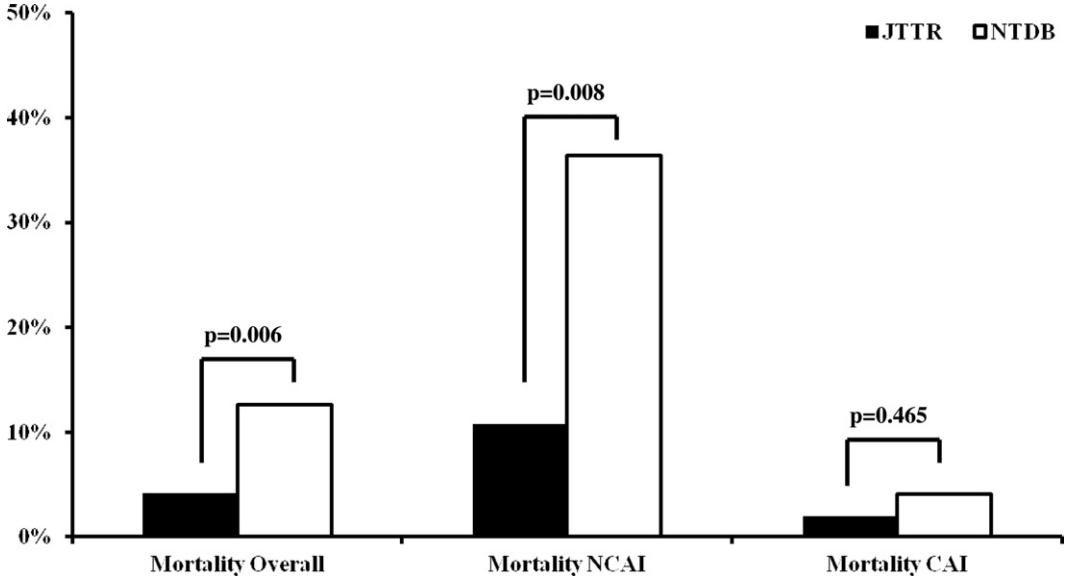

Fig 3. Matched comparison Joint Theater Trauma Registry (*JTTR*) vs National Trauma Data Bank (*NTDB*). *CAI,* Compressible arterial injury; *NCAI,* noncompressible arterial injury.

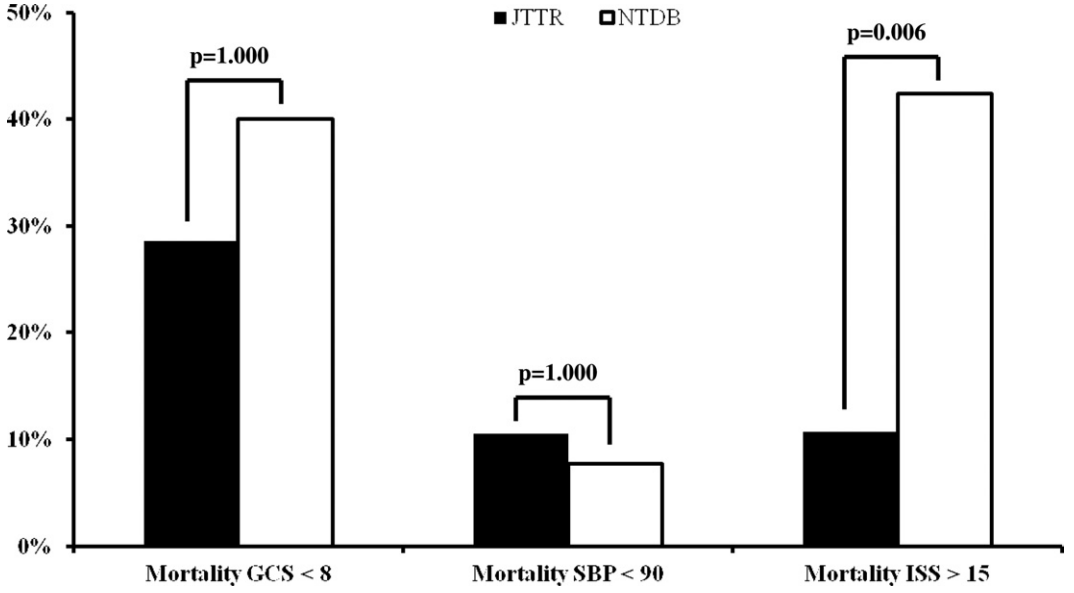

Fig 4. Matched comparison Joint Theater Trauma Registry (*JTTR*) vs National Trauma Data Bank (*NTDB*). *GCS,* Glasgow Coma Scale; *ISS,* Injury Severity Score; *SBP,* systolic blood pressure.

to defined levels of surgical care, are also likely of significant importance.[31] The JTTS consists of echelons of combat casualty care, referred to as "levels" or "roles" (the latter term is more commonly used by the North American Treaty Organization in the current conflict in Afghanistan), ranging from rudimentary (role 1) to comprehensive (role 5) in the capabilities they provide. Strategies unique to vascular injury used at each of these levels of care have been documented by this group in the past.[31] Key interventions at each of these echelons are likely to affect the outcome after vascular injury. As suggested in a recent report by Kotwal et al,[11] it is possible that the use of tourniquets and other tactical combat casualty care maneuvers in the prehospital environment may have contributed to improved survival in the military cohorts. In separate supporting reports, Kragh et al[10] and Beekley et al[9] have also demonstrated improved survival with tourniquet application to extremity or compressible sites of hemorrhage, particularly when used before the onset of shock. Additionally, as documented by Chambers et al,[32] combat injuries in pres-

ent theaters of conflict are commonly evacuated to surgical facilities within 30 minutes of injury, affording them access to life-saving maneuvers such as resuscitation and surgical control of hemorrhage, which likely contribute to improved survival compared to historical military reports.[31]

This study has limitations worth noting, including its design as a retrospective review of trauma registries. Although the JTTR was modeled after the NTDB and contains the same injury and outcomes data fields, both registries are subject to coding and data entry errors. Additionally, it should be emphasized that both registries capture mortality data on patients who have survived to receive care at medical facilities. In the case of the military cohort, these deaths are classified as died of wounds. The mortality in neither cohort includes those who died from hemorrhage or other causes before arrival at a medical treatment facility, an outcome classified as killed in action in the military system. As such, this study does not provide a complete view of the lethality of arterial injury, such as that reported by Tai et al[33] from the British military which included analysis of those killed in action. These limitations notwithstanding, both the JTTR and NTDB have been used extensively to report on vascular injury patterns, methods of management, and short-term outcomes in the past.[34-40]

A second limitation relates to the use of dated cohorts from the JTTR and NTDB (from 2003-2006). These dates were chosen in order to obtain a representation of wartime arterial injury in US service personnel during a period in which hostilities were the greatest and occurring in two simultaneous theaters of war. This military cohort was selected to provide injury and outcomes information during a period in which the demands on the US combat casualty care system were the utmost. These inclusion dates were also chosen to provide use of a single NTDB Research Data Set from version 7.0 (2002 to 2006) without having to patch data from the subsequent version. Using older cohorts from the two registries limits the degree to which the findings from this study apply to arterial injury and outcomes today. However, because hemorrhage control and resuscitation practices have improved and wartime hostilities have decreased over time, it is likely that use of the older cohort introduces a conservative bias to the findings of this study.

The most significant limitation relates to this study's ability to compare arterial injury distribution and outcomes in two such contrasting populations. To address these differences, the technique of propensity scoring and matching was used to identify and compare groups with similar age, injury severity, and initial hemodynamics. Although this methodology permitted matching across several key variables that are known to influence outcome, it is important to note that the discrepancies in mechanisms between these two populations could not be completely corrected due to the preponderance of explosion-related mechanisms among combat injured. Additionally, whereas propensity scoring is an accepted method to improve comparability, it results in smaller cohorts and is not likely to correct for all the differences between civilian and wartime injury.[18,19]

The differences in mechanisms between the two populations should also be highlighted as a significant limitation of any direct comparison between military and civilian counterparts. As vascular trauma due to blunt mechanisms is among the most lethal of injury patterns, and was more predominant among civilian patients, this might provide some explanation for the discrepancies in outcomes observed in our review. Conversely, vascular injuries at multiple sites were more common after the explosive mechanisms associated with combat injury.

Other differences related to mechanism are simply not adequately discernible from the data available from these trauma registries. The JTTS lists only three types of mechanisms: penetrating (gunshot/stab wound), blunt, and explosive. In practice, however, it is important to consider that explosive mechanisms commonly represent complex forces with penetrating, blunt, and shearing effects. The present construct of JTTS and NTDB data simply does not facilitate the ability to discern the relative contribution of each of these components and their correlation to the types of injuries observed (occlusion, transaction, etc), or subsequent outcome. It is also important to consider that explosive mechanisms commonly result in poly-trauma. The effects of these multiple injuries, particularly for associated injuries such as traumatic brain injury, may contribute significantly to subsequent survival and outcome. It should be noted that, even among the matched cohorts, GCS was more commonly less than or equal to 8 among JTTR patients. While GCS does not universally correlate with the anatomic injury patterns associated with brain injury, this finding is suggestive that these injuries were more common and perhaps more severe among JTTR patients.

Despite these limitations, the findings of injury distribution and outcomes from the JTTR cohort alone are important. Characterization of injury distribution and mortality in US service personnel during a hostile time period in two theaters of war establishes a benchmark for military planners as they consider training and positioning of surgical capability and patient movement. Comparing the findings from this JTTR cohort to a recognized civilian trauma database such as the NTDB provides novel context if not exact comparison.

CONCLUSIONS

Mortality of injured service personnel who reach a medical treatment facility after major arterial injury is 8% and compares favorably to a matched civilian standard. One-quarter of arterial injuries in combat are in an anatomic region not conducive to compression or tourniquet application and, thus, are more prone to shock and death. Acceptable mortality rates within the military cohort are related to key aspects of an organized JTTS, including prehospital tactical combat casualty care, rapid medical evacuation to forward surgical capability, and implementation of clinical practice guidelines. Aspects of this comprehensive combat casualty care strategy may translate and be

of value to management of arterial injury in the civilian sector.

AUTHOR CONTRIBUTIONS

Conception and design: NM, JD, BP, WC, TR
Analysis and interpretation: NM, JD, DS, BP, BT TR
Data collection: NM, JD, DS, BP, BT, TR
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Critical revision of the article: NM, JD, WC, LB, TR
Final approval of the article: NM, JD, WC, DS, BP, WC, BT, LB, TR
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